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Variations in Yield and Carbohydrate Content of Two Seeded Native Grasses

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VARIATIONS IN YIELD AND CARBOHYDRATE CONTENT OF TWO SEEDED NATIVE GRASSES

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May 18, 1957

VARIATIONS IN YIELD AND CARBOHYDRATE CONTENT OF TWO SEEDED NATIVE GRASSES

Jimmie D. Dodd

During the past drought years the farm lands of the Great Plains have suffered greatly. The loss of grazing land during this time has been extensive, due to wind and water erosion. Much of this land is now being seeded to native grasses. If these grasses are to produce a maximum amount of foliage proper handling will be necessary. The purpose of this study was to determine the effects of different times of clipping on the yield and carbohydrate content of seeded blue grama (Bouteloua gracilis) and side-oats grama (Bouteloua curtipendula).

The grasses were seeded on April 18, 1955, on a lowland site. The top soil was of a silty clay loam texture. The deficient rainfall during the growing seasons of 1955 and 1956 was supplemented by irrigation.

The experimental area was divided into plot A (blue grama) and plot B (side-oats grama). Each plot was divided into 6 series which were further divided into 6 quadrats. Series A6 and B6 were not clipped during the experiment. Series A1 and B1 were first clipped on September 1, 1955, and on the first of each month throughout the 1956 growing season. Series A2 and B2, A3 and B3, A4 and B4, and A5 and B5 were first clipped on June 1, July 1, August 2, and September 3, 1956, respectively, and on the first of each succeeding month thereafter.

Blue grama was clipped at a height of 2 inches while side-oats grama was clipped at 3 inches. The herbage removed was air dried, weighed and converted to pounds per acre. Growth in height was also recorded each month.

A sample 6 inches square and 4 inches deep was removed each month of the growing season from September, 1955, to November, 1956, from the unclipped series. A similar sample was removed from each clipped series a month following initial clipping. Ascending paper chromatography was used for the qualitative and quantitative determinations of reducing sugars, sucrose, starch, and fructosans from these samples. Depth and extent of roots was determined at the end of the experiment.

Soil moisture was determined periodically, during the 1956 growing season, to a depth of 5 feet. Samples were taken in duplicate and an average per cent moisture for the 2 samples was recorded for each depth.

Range in yield in 1956 was from 2,324 pounds per acre in series A3 to 6,058 pounds in series B5. Lowest yield for side-oats grama was the 3,229 pounds produced by B2.

Carbohydrate reserves followed a pattern closely related to the rate of growth. Amount stored usually decreased when growth was rapid and increased when it was slow. For example, the total carbohydrate content of series A1 was 28.8 per cent on July 1, 1956, after a month of slow growth. However, growth was rapid during July and it decreased to 15.0 per cent by August 1. Series A1 reached a peak of 34.8 per cent on September 3 and decreased to 23.8 per cent by November 2. On November 2 series A4 had 19.3 per cent, which was the least of all series. Series A5, had 23.6 per cent and the control 31.4 per cent.

The carbohydrate content in series B1 reached a peak of 32.1 per cent on September 3, 1956, and decreased to 18.1 per cent on November 2. Like blue grama, B4 had less than any other series with 16.1 per cent. B1 had 18.1 per cent and the control 30.1 per cent on the same date.

Sucrose content in both grasses usually increased with the approach of dormancy, while starch and fructosans remained approximately the same or decreased. The fluctuations in carbohydrates were caused mainly by sucrose and fructosans. Starch and fructosans were the largest contributors to the reserve foods and in most cases made up at least 70 per cent of the total.

The blue grama crowns removed from the control at the end of the experiment weighed 18.9 grams and had 736 roots, the longest of which penetrated to 62 inches. A crown from A1 weighed 14.6 grams and had 519 roots. The crown from B6 weighed 41.4 grams and had 22 rhizomes and 1,052 roots, the longest of which penetrated to 92 inches. The crowns from B1 weighed 21.8 grams and had 2 rhizomes and 514 roots. Thus delayed clipping not only resulted in increased yield and carbohydrate content, but also permitted a better development of the root systems.

The effects of early and continued clipping on these newly seeded grasses were reduced vigor, yield, root reserves, quantity and size of roots, and size of crowns.

INTRODUCTION

During the past drought years the farm lands of the Great Plains have suffered greatly. The loss of grazing land during this time has been extensive, due to wind and water erosion. Much of this land is now being seeded to native grasses. This reseeded grassland will need proper handling if it is to produce a maximum amount of high quality forage. The establishment of the seedlings will depend on the plants' ability to manufacture and store carbohydrates in excess of those necessary for current growth. Any system of grazing that permits frequent removal of herbage and thus retards manufacture and storage of carbohydrates may result in depletion or destruction of the grass (McCarty 1938).

The productivity of the range land depends largely on the vigor and persistence of the herbaceous perennials that are the principal forage producing plants of this region. McCarty and Price (1942) report that

> . . . since plants die back near the soil level upon approach of winter, it is imperative that they should make proper growth and store sufficient food during the growing season to carry them through the winter period and to produce initial growth in the spring.

In any system of herbage removal, whether by clipping or grazing, it is important to know the effects of defoliation upon the herbage yield and amount of carbohydrates stored in the underground parts. If a high rate of productivity is to be maintained, some knowledge is necessary concerning the intensity of use to which each grass species can be subjected (Kinsinger 1953).

The experiment reported herein was an effort to determine the influence of different intensities of clipping on the herbage yield and carbohydrate content of the roots, rhizomes, and crowns of blue grama (Bouteloua gracilis)[1] and side-oats grama (Bouteloua curtipendula). Both are warm season perennial grasses, but blue grama is classified as a short grass and side-oats grama as a mid grass.

There appears to have been considerable work done on the effect of clipping or grazing upon carbohydrate reserves stored in the roots and other underground plant parts. However, very little of this work has been done in the Great Plains, especially with recently seeded grasses. It was hoped that indications could be established as to the proper time for grazing in respect to yield and carbohydrate content of seeded grasses.

RELATED STUDIES

Since early times it has been maintained that if plants were supplied with the small amounts of mineral constituents found in the ash, the remainder of their substance could be gathered from the surrounding air, much knowledge has accumulated concerning the role of carbohydrate accumulation and its use in the organism.

Hanson and Stoddart (1940) in their studies with bunch wheat grass (Agropyron inerme) found that heavily grazed plants had 14.33

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[1] Nomenclature of grasses follows Rydberg's "Flora of the Prairies and Plains of Central North America."

per cent total carbohydrates while protected plants had 17.77 per cent. Heavy grazing also reduced root systems, seed production, and size and number of plants.

Sampson and McCarty (1930), working with needle grass (Stipa pulchra), found an inverse correlation between the annual march of the carbohydrates and the growth rate. Accumulation of food was related to low or declining growth velocity and was most active near the close of the annual growth cycle. Grazing or clipping once or twice early in the growth cycle had little if any influence on the total forage yield and did not prevent the accumulation of maximum amounts of carbohydrates in the late part of the annual growth period. McCarty and Price (1942) found this to be true in grasses and herbs of the Wasatch Mountains. McCarty (1938) also found that in mountain brome (Bromus carinatus), carbohydrate storage except for the hemicellulose fraction, was inversely related to the rate of growth of the herbage. Maximum storage occurred during the autumn period after current seasonal and secondary herbage growth was complete. The starch values exceeded the sugar values in both herbage and basal organs. He concluded that starch and sugars were the most potent stored foods and were necessary for incipient root and shoot growth.

Moran et al. (1953) determined starch and sugars in Ladino white clover. Defoliation caused a depletion of the carbohydrate reserves in both stolons and roots. The depletion was greater when the carbohydrate level was high than when it was low. The amount of stored carbohydrates was affected by the height and frequency of defoliation. The quantity

of new foliar growth produced after defoliation was closely related to the level of carbohydrates at the time of defoliation. Grandfield (1935) found that early and frequent cutting of alfalfa resulted in a relatively low carbohydrate content of the roots. Bukey and Weaver (1939), working with big bluestem and little bluestem (Andropogon scoparius and Andropogon gerardi) found a marked decrease in the percentage of invert sugar and hydrolyzable material when these 2 prairie grasses were clipped severely.

Sullivan and Sprague (1949) found that perennial ryegrass (Lolium perenne) roots underwent rapid losses in sucrose and fructosans during the early part of a greenhouse experiment on the effect of temperature, but these losses were partly replaced later under low temperature conditions. Sullivan and Sprague (1953) also found that sucrose and fructosans were highest in orchard grass (Dactylis glomerata) which was low in nitrogen.

Graber (1931) found that root growth and top growth of several grasses varied inversely with the frequency of defoliation. The carbohydrate reserves became a limiting factor if regeneration of top growth was stimulated by abundant nitrogen after frequent removal. Graber et al. (1927) studied the responses of alfalfa and several other herbaceous plants to the removal of foliage and found a reduction in both root and top growth following frequent defoliation. Winter injury also increased with frequent defoliation and low concentrations of reserve materials in the roots. New growth was started after each defoliation at the expense of root reserves. If these reserves were

not replaced between clippings, the amount of new growth diminished.

Albert (1927) found that the percentage of nitrogen and reserve carbohydrates in alfalfa roots tended to be lower in plants cut at immature stages than in those cut when mature. They contained little starch but were relatively high in sugars in spring and fall. The reverse was true in the summer.

METHODS OF STUDY

The experimental plot was located 0.5 miles west of Hays, Kansas, on the Fort Hays Kansas State College farm (Fig. 1). The study area consisted of 2 plots, each of which was divided into 6 series 3 feet apart. Each series contained 7 rows 8 inches apart and 28 feet long. The series were divided into meter-square quadrats. The outside row in each series was considered a buffer and was not used for data. The blue grama seed was obtained from the local Soil Conservation Service and had a germination of 23.0 per cent. The side-oats grama seed was produced on the college farm and had a germination of 79.0 per cent. The grasses were seeded on April 18, 1955. The plants were thinned to 1 plant every 4 inches during August of the first year and to 8 inches at the beginning of the second growing season. Throughout the experiment competition from weeds was reduced to a minimum by hoeing and the use of 2, 4 dichlorophenoxyacetic acid.

Each series was clipped at various time throughout the growing seasons as shown in Table I. The control series, A6 and B6, were not clipped. The blue grama plot (A) was clipped by hand at a height of

2 inches, and the side-oats grama plot (B) was clipped at 3 inches to simulate moderate grazing. The herbage was air dried, weighed, and converted to pounds per acre.

Textural analyses were made on soil samples removed from the soil surface, at a depth of 6 inches, 12 inches, and each succeeding foot to a depth of 5 feet. These samples were analyzed according to the Bouyoucos method (Bouyoucos 1936). Soil moisture determinations were made each month during the second growing season. Samples were taken from 0 to 6 inches, 6 to 12 inches, and from each succeeding foot to a depth of 5 feet. Moisture content was determined by drying for 24 hours at 105°C.

The trench method was used to study the development of roots of an individual plant in each control series at the end of each growing season (Weaver 1919). After excavation, the depth and lateral spread of the roots was determined by removing the soil from around the roots with an ice pick. Notes were taken on the growth and development of the crowns, rhizomes, and top 4 inches of roots each month. An average of 5 crowns from each series were studied during the first season while 1 representative crown from each series was studied during the second season.

Samples were removed from each series for chemical analysis 1 month following the initial clipping (Table I). The samples were taken from a block of soil 6 inches square and 4 inches deep containing the crowns, rhizomes, and roots. Soil was removed with a fine spray of

Figure 1. General view of experimental area during the second growing season showing blue grama in the foreground and side-oats grama in the background.

Table I. Dates of clipping foliage (X) and removing samples for carbohydrate analysis (O)

Date	TREATMENTS											
	A1 and B1		A2 and B2		A3 and B3		A4 and B4		A5 and B5		A6 and B6	
Sept. 1 55	X											O
Nov. 4 55		O										O
June 1 56	X	O	X									O
July 1 56	X	O	X	O	X							O
Aug. 2 56	X	O	X	O	X	O	X					O
Sept.3 56	X	O	X	O	X	O	X	O	X			O
Nov. 2 56		O		O		O		O		O		O

water. The plant parts were blotted dry, placed in an oven at 90°C. for 30 minutes, and finally dried for 14 hours at 70°C. Preparation of the material for drying was usually completed within 2 hours after its removal from the field. Following the grinding of the samples, they were again dried at 80°C. for 4 hours and stored in air-tight glass bottles (Loomis and Shull 1937).

The carbohydrates determined were reducing sugars, sucrose, starch, and fructosans. According to Bacon and Edelman (1951, as discussed in Paech and Tracey 1955) the fructosans comprise a group of reserve polysaccharides found in angiosperms. They may constitute the sole reserve polysaccharide of the plant or occur along with starch. In grasses, fructosans were found distributed throughout the plant as reserve polysaccharides. They were hydrolyzed by dilute acid and identification of the resulting fructose was possible.

A 3-gram portion of each sample was used for the complete carbohydrate analysis. The reducing sugars and sucrose were extracted from 3 grams of the finely ground material mixed with 2 grams of calcium carbonate and an excess of 80 per cent ethyl alcohol. The solution was heated on a hot plate below boiling and stirred continuously for 1 hour. It was then filtered and the remaining residue was covered with an excess of 80 per cent ethyl alcohol, heated, and stirred for an additional 30 minutes. The solution was again filtered, and the filtrates were combined and cooled. If any precipiate formed, further filtering was necessary. The filtrate was finally placed in an evaporating dish on a hot plate and heated until the alcohol was all

evaporated. It was sometimes necessary to add distilled water to keep the filtrate from becoming dry (Williams and Bevenue 1953).

The starch and fructosans were extracted from 1 gram of the residue remaining after the reducing sugars and sucrose had been extracted. They were extracted with 30 ml. of 0.25 per cent oxalic acid for 1 hour at about 80°C. The solution was then filtered under suction and the residue washed with 12 ml. of hot water. Five drops of Taka-Diastase were added to 1 ml. of the filtrate at 45°C. to complete hydrolysis (Sprague and Sullivan 1950).

A modification of Williams' method for ascending paper chromatography was employed for the determination of reducing sugars, sucrose, and the starch and fructosan hydrolyzed products (Williams 1948, as discussed in Block et al. 1955). The equipment used for this method consisted of an air tight chamber of suitable size, a frame of glass to support the paper chromatograms, and a trough to hold the developing solvent. Filter paper sheets were used as the inert support for the substances being analyzed. The filter paper chromatograms were 10.5 cm. wide and 35 cm. long. Known standards of sucrose, fructose, and glucose were run in triplicate. Each sugar was run at various percentage levels and the resulting R_f values and areas were recorded.

Spots of the unknown filtrates, 4 microliters in quantity, were placed 3 cm. from the base of the paper and 2.5 cm. apart. They were replicated 3 times. The spots containing the hydrolyzed products of starch and fructosans were dried for 5 minutes with a heat lamp, the other spots were air dried for 15 minutes before being suspended in an

irrigating solvent of butanol: pyridine: Water in a v/v ratio of 6:4:3, respectively. The chromatograms were allowed to develop for 8 hours in an air tight chamber at a constant temperature of 40°C. Upon completion of development, they were removed from the chamber and dried with hot air for 20 minutes. The chromatograms to be used for the determinations of reducing sugars, hydrolyzed starch and hydrolyzed fructosan were sprayed with a solution of aniline oxalate. This solution contained 0.05 N solution of oxalic acid with 0.9 ml. of aniline per 100 ml. of solution. The chromatograms were then dried in an oven at 105°C. for 20 minutes. The resulting spots were brown on a light tan background. The chromatograms to be used for sucrose determination were sprayed with a solution containing 0.5 grams of resorcinol and 2 ml. of concentrated hydrochloric acid to 100 ml. of ethanol. The chromatograms were then dried in an oven at 88°C. for about 5 minutes. The resulting spots were reddish-brown on a white background, fading on standing to gray spots on a white background.

The qualitative determinations were made by comparing the R_f value of the sample with that of known sugars. R_f values were determined by dividing the distance the unknown spot moved by the distance the solvent front moved.

The quantitative determinations were made with a Photo-volt densitometer. The areas obtained for the known standard sugar solutions were plotted on semi-log paper and were used in the determinations of the quantity of the unknown samples. The light transmission curves were plotted on graph paper, and a base line was drawn at the best

apparent position (Fig. 2). The areas under the curves were then determined with a planimeter. In the curves that showed slight overlap, the correct dividing line was approximately that drawn from the lowest point of the valley between the peaks of the curves perpendicular to the base line. The resulting area was recorded and compared to the area of a known standard plotted on semi-log paper, and a direct reading in percentage was obtained for the reducing sugars and sucrose. Since the starch and fructosans had been hydrolyzed, the dilution factor and the conversion factor of 0.9 had to be calculated before the true percentage could be obtained. Accuracies of ± 5 per cent have been obtained with this method (Block et al. 1955).

ENVIRONMENTAL CONDITIONS

The top soil of the experimental plot was dark brown in color and extended to a depth of approximately 15 inches. It had a good granular structure and was of a silty clay loam texture (Table II). Beneath this was a yellowish-brown transition layer which extended to about 26 inches. The typical subsoil, which was yellow in color and of a prismatic structure, occurred from about 26 to 50 inches. The prisms averaged 2.5 inches in diameter and 6 inches in length. The lime layer began at 26 inches and extended to a depth of 60 inches. This layer consisted of heavy white streaks throughout the subsoil with heaviest deposits at about 42 inches. The clay content varied from 31.3 per cent near the surface to 44.0 per cent at a depth of 2 feet and 56.7 per cent at 5 feet.

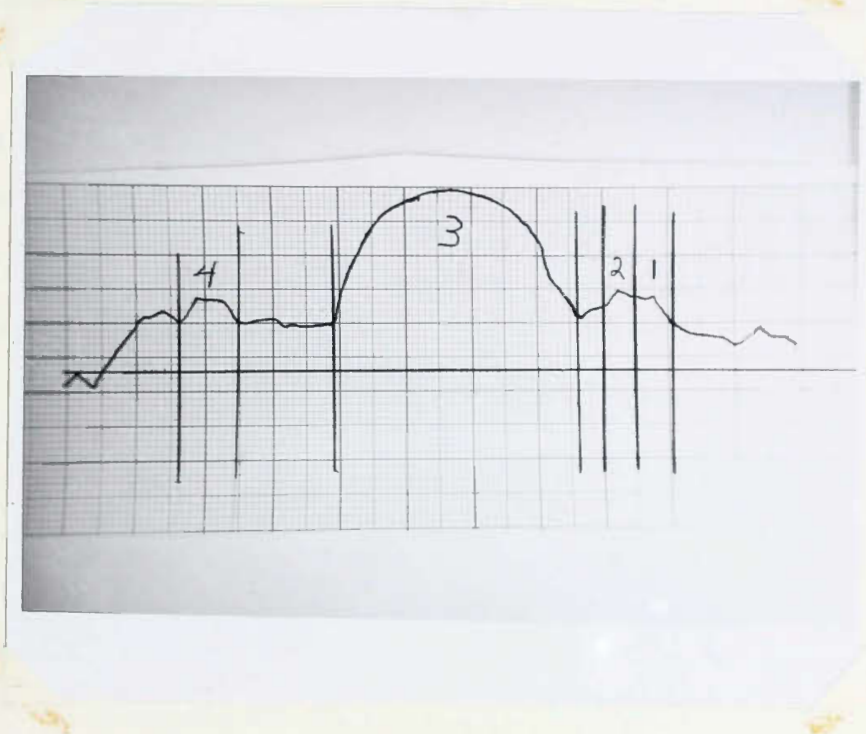

Figure 2. The light transmission curves for a sample containing: (1) fructose, (2) glucose, (3) sucrose, and (4) an unidentified sugar.

Table II. The results of mechanical analyses of the soil from the experimental plot

	Depth in inches at which samples were taken						
	Surface	6	12	24	36	48	60
Sand >0.05 mm.	20.0	14.0	16.0	6.6	5.3	5.3	5.6
Silt 0.05-0.002	48.7	54.7	48.7	49.4	49.1	49.1	37.7
Clay <0.002	31.3	31.3	35.3	44.0	45.6	45.6	56.7

This high clay content resulted in the presence of many cracks up to 0.25 inch in width when dry. The concentration of lime along the edges of these cracks was heavy.

The 86-year precipitation average at Hays, Kansas, is 23.05 inches, of which 18.03 inches fall during the growing season, April to September, inclusive. The precipitation, average temperature, and departure from normal for the growing season of 1955 and 1956 are presented in Table III. Low precipitation and high temperatures resulted in poor growing conditions during the study. The temperature was over 100°F. for 26 days in 1955 and 35 days in 1956. The low precipitation was compensated for by irrigation water applied as necessary to keep the grass from becoming completely dormant.

There was never an ample supply of soil moisture at the lower depths during 1956. Irrigation water did not reach below 3 feet and soil moistures fluctuated very little below this depth. On September 29 the soil from 36 to 48 inches contained only 9.1 per cent and from 48 to 60 inches 11.3 per cent. Up until this time the soil moistures from 36 to 60 inches had ranged from 13.6 to 17.9 per cent. There was very little soil moisture in the top 3 feet after June 11. Up to this date the soil moisture had ranged from 9.3 to 23.8 per cent. From June 11 to September 29 the soil moistures in the top 3 feet varied from 6.7 to 17.2 per cent (Table IV). The above data represents total moisture content. However, the hygroscopic coefficient for an adjacent pasture area with a similar soil type is 11 to 14 per cent (Albertson and Weaver 1944). Since it is ordinarily assumed that only moisture in

Table III. Precipitation, average temperature, and departures from normal for growing seasons of 1955 and 1956 at Hays, Kansas[2]

Month	Precipitation (inches)	Irrigation (inches)	Departure from Normal	Average Temperature	Departure from Normal
1955					
April	3.0	0	0.8	57.2	4.3
May	2.5	0.5	-0.5	65.1	2.7
June	3.7	0	-0.4	69.9	-2.8
July	2.1	1.3	0.5	83.2	3.9
August	0.5	11.0	8.4	79.9	2.0
Sept.	7.6	1.8	7.6	70.6	1.4
1956					
April	1.3	0	-0.9	48.6	-5.0
May	1.4	0	-2.1	65.8	2.8
June	0.4	0.5	-3.2	78.0	3.8
July	2.8	2.5	2.4	78.8	-1.8
August	1.1	4.5	2.5	80.0	1.1
Sept.	0.1	0	-2.2	71.3	1.3

[2]Climatological Data, U. S. Department of Commerce, Weather Bureau, Topeka, Kansas

Table IV. Total soil moisture at various depths in the experimental plot during the 1956 growing season

Date	DEPTH IN INCHES					
	0-6	6-12	12-24	24-36	36-48	48-60
4- 8-56	23.5	23.9	20.7	19.0	17.6	16.8
4-23-56	18.4	20.4	19.4	17.8	15.1	13.9
4-29-56	19.7	20.8	19.6	18.5	16.9	16.8
5- 7-56	20.4	20.6	20.1	16.9	16.7	17.8
5-28-56	17.3	14.9	17.7	15.8	14.9	16.1
6- 4-56	12.1	13.4	17.3	17.7	15.7	17.6
6-11-56	12.6	9.3	14.3	14.4	14.5	15.8
6-20-56	6.7	9.1	11.1	14.1	15.1	16.8
6-26-56	9.2	12.4	14.4	15.4	16.7	17.9
7-14-56	15.0	15.9	15.3	11.6	-	-
8-31-56	16.8	17.2	16.6	12.9	13.6	13.9
9-29-56	8.4	10.3	15.1	8.9	9.1	11.3

excess of the hygroscopic coefficient is available, it is apparent that little was available for growth.

RESULTS

It was necessary to mulch and irrigate the plots after seeding in order for the seeds to germinate and start growth. The first plants emerged on May 4, 1955, 15 days after planting, but germination was not complete for over a week.

Growth was quite slow until after the middle of July, but from July 11 to September 1 the height of blue grama increased from 2.9 to 4.0 inches. During this same period side-oats grama increased from 3.8 to 6.2 inches. Restoration of soil moisture during the fall and winter enabled the grasses to make rapid growth during the following spring.

HERBAGE YIELDS

Blue Grama. Series A1 of the blue grama plot was clipped on September 1, 1955, near the end of the growing season (Table I), and yield was at the rate of 190 pounds per acre. Growth was resumed following clipping, but it was slower than the unclipped series when dormancy occurred (Fig. 3).

This series was again clipped on June 1, 1956, when it produced 596 pounds. On this date series A2 was clipped for the first time and yielded 568 pounds. This would indicate clipping the previous fall had not hurt the early growth of the grass in series A1, which averaged 5 inches

Figure 3. Unclipped blue grama (left) compared to plant clipped on September 1, 1955, (right) as they appeared on October 1. Note the sparse seed stalks on clipped plant.

in height while that in series A2 was 4 inches.

On July 1 the grass in series A3 had a height of 7 inches, while that in A1 and A2 which had been previously clipped was 2 inches (Table V). Series A3 produced 496 pounds per acre as compared to 180 for A1 and 148 for A2. At this time the grasses in all series were suffering from lack of moisture. There were some seed stalks present in the boot, but none had emerged.

None of the plants was dormant on August 2 and all had seed stalks present. The grass in series A4 had the greatest number of seed stalks and was also the tallest. Series A1, which had now been clipped a total of 4 times, was 5 inches tall with seed stalks 9.5 inches tall. Series A2, clipped twice, was 6 inches tall with seed stalks 11 inches tall. The height of seed stalks in series A3 and A4 was 12 and 15 inches, respectively. The yield was 1,185, 1,093, 1,084, and 1,839 pounds per acre for series A1 to A4, respectively (Table VI).

On September 3 series A1 yielded 697 pounds per acre. Despite the fact that it had been clipped 4 times previously, the yield compared favorably with that from the other clipped series. However, A5 produced more than 4 times as much as series A1, A2, or A3 (Table VI). During August, the center of the crowns in the A1 series began to die, although there was little difference in the crown development of the other series. Foliage heights ranged from 3 to 12 inches with the maximum occurring in the series not yet clipped (Fig. 4). All series contained a large number of seed stalks which averaged 7 to 16 inches in height.

Table V. Growth of blue grama in inches during 1956

Date	TREATMENT A1	A2	A3	A4	A5	A6
June 1	5.0	4.0				
July 1	2.0	2.0	7.0			
August 2	5.0	6.0	6.0	9.0		
September 3	3.0	3.0	5.0	6.0	11.0	12.0
Total Growth	15.0	15.0	18.0	15.0	11.0	12.0

Table VI. Yield of blue grama foliage in pounds per acre during 1955 and 1956

Series	Sept. 1 '55	June 1 '56	July 1 '56	Aug. 2 '56	Sept. 3 '56	Total Yield '56
A1	190	596	180	1,185	697	2,658
A2		568	148	1,093	602	2,411
A3			496	1,084	744	2,324
A4				1,839	869	2,708
A5					3,000	3,000

Figure 4. Unclipped blue grama plant (left) compared to a plant clipped 4 times (right) as they appeared on September 3, 1956. Note the large number of seed stalks on the unclipped plant.

The range in total yield for plot A in 1956 was from 2,324 to 3,000 pounds per acre (Table VI). Series A1 yielded 2,658 pounds per acre in 1956. Delayed clipping of A5 until the end of the growing season allowed the grass to grow continually without interruption. In all cases the largest yields were produced in July and August. Over 60 per cent of the yield from series A1, A2, and A3 resulted from growth during these 2 months (Table VI).

Side-Oats Grama. The grasses in plot B were clipped on the same dates as those of the corresponding series in plot A (Table I). After 1 season of growth the yield from series B1 was at the rate of 196 pounds per acre. Growth was resumed after the September first clipping, but on October 1 the clipped plants were shorter and had produced fewer seed stalks than the unclipped plants (Fig. 5).

This series was clipped again on June 1, 1956, when the grass was 7 inches tall. Yield was 748 pounds per acre. Series B2, clipped for the first time, was 8 inches tall and produced 727 pounds. Thus, the results of clipping at the close of the first growing season were similar in both blue grama and side-oats grama.

On July 1 the grass in series B3 was 12 inches tall while that in B1 and B2, which had been previously clipped, was 6 inches tall (Table VII). Series B3 produced 1,220 pounds per acre while series B1 and B2 produced 543 and 430 pounds, respectively (Table VIII).

On August 2, series B1 was 6 inches tall with seed stalks 17 inches. Series B2 was 7.0 inches tall. The height of seed stalks in series B2,

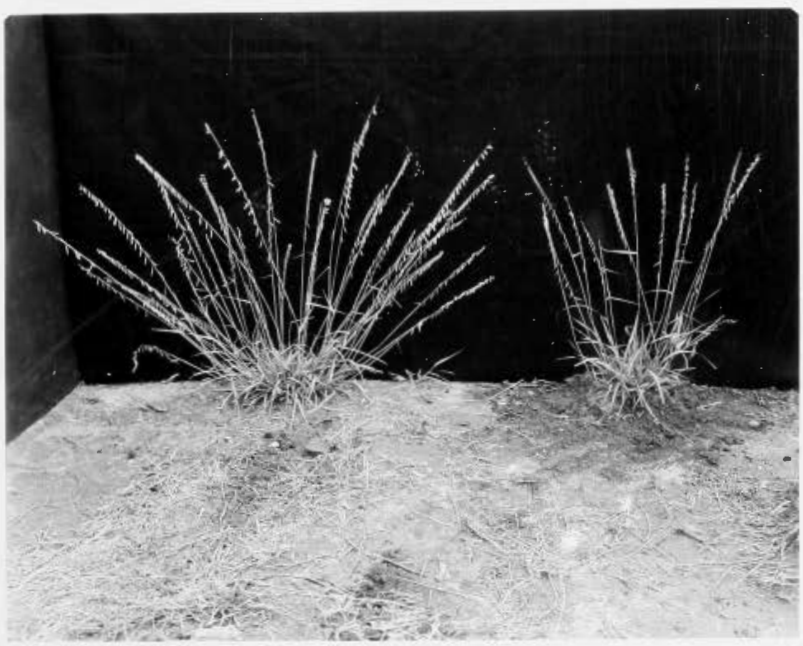

Figure 5. Unclipped side-oats grama plant (left) compared to clipped plant (right) on October 1, 1955.

Table VII. Growth of side-oats grama in inches during 1956

	TREATMENT					
Date	B1	B2	B3	B4	B5	B6
June 1	7	8				
July 1	6	6	12			
August 2	6	7	8	12		
September 3	5	5	8	9	13	14
Total	24	26	28	21	13	14

B3, and B4 was 19, 19, and 24 inches, respectively. Series B4, as yet unclipped, was 12.0 inches tall. The yields were 1,444, 1,206, 1,385, and 3,752 pounds for series B1 to B4, respectively. Series B1 again produced more than series B2 and B3. This was also true in the corresponding blue grama series.

On September 3 series B1 yielded 859 pounds per acre. Yields for B2, B3, B4, and B5 were 876, 1,241, 1,181, and 6,058 pounds, respectively (Table VIII). During August, the center of the crowns in the B1 series began to die, but there was little difference in the crown development of the other series. Foliage heights at this time ranged from 5 to 14 inches with the maximum occurring in the series not yet clipped. A large number of seed stalks 16 to 26 inches in height were present in all series (Fig. 6).

Series B1 had a total yield of 3,593 pounds per acre for the growing season of 1956; this was 355 pounds greater than B2, but 253 pounds less than B3. Series B4, although clipped only twice, produced 4,933 pounds while series B5, clipped only at the close of the second growing season, produced 6,058 pounds. Clipping only at the close of the second growing season had the same effect as was exhibited by the corresponding blue grama series.

The pattern of yield in side-oats grama was the same as in blue grama. The largest yields were produced in July and August. Over 65 per cent of the yield from series B1, B2, and B3 resulted during these 2 months (Table VIII).

Table VIII. Yield of side-oats grama foliage in pounds per acre during 1955 and 1956

Series	Sept. 1 '55	June 1	July 1	Aug. 2	Sept.	Total 1956
B1	196	748	543	1444	859	3593
B2		727	430	1206	876	3239
B3			1220	1385	1241	3846
B4				3752	1181	4933
B5					6058	6058

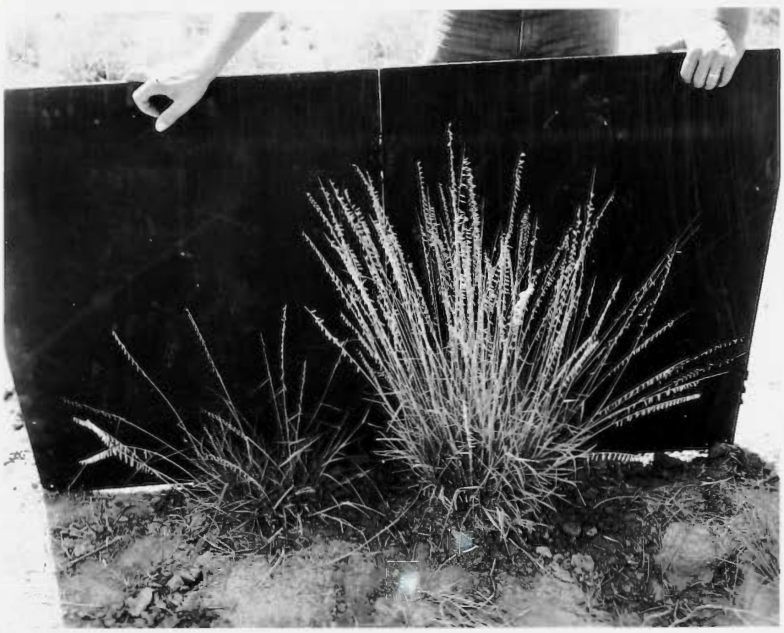

Figure 6. An unclipped side-oats grama plant (right) compared to a plant clipped 4 times (left) as they appeared on September 3, 1956.

The blue grama and side-oats grama clipped only once during the 1956 season had an exceptionally high yield when compared to the clipped plants. This high yield was probably the result of irrigation at intervals throughout the growing season.

CARBOHYDRATE CONTENT

The spots of the carbohydrates on the filter paper chromatogram present in the samples were well separated and easily identified by the use of R_f values (Fig. 7). Fructose and glucose both moved a greater distance than did sucrose or an unidentified sugar which had an R_f value lower than any of the known standards (Table IX). Fructose moved the greatest distance, followed in order by glucose, sucrose, and the unidentified sugar. As indicated by the R_f values, fructose and glucose were close together, but were easily separated into individual spots with the aid of a Photo-volt densitometer.

Blue Grama. There was a great deal of fluctation in the total carbohydrates of the various blue grama series throughout the growing season (Fig. 8). The amounts of total readily available carbohydrates[1] of the underground parts in the control quadrats varied inversely with the rates of growth. When rapid growth was taking place under favorable conditions, the plants used both stored and currently synthesized

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[1]Total readily available carbohydrates refers to the sum of the reducing sugars, sucrose, fructosans, and starch.

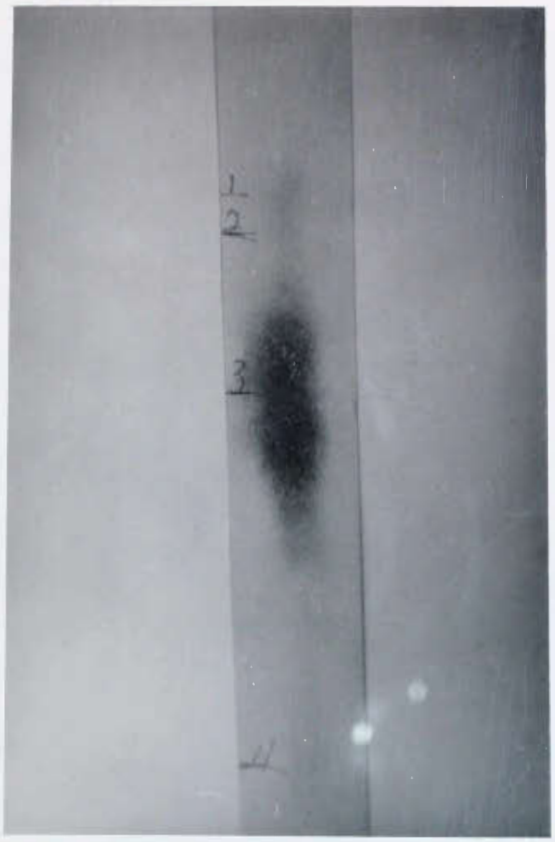

Figure 7. A developed chromatogram showing: (1) fructose, (2) glucose, (3) sucrose, and (4) an unidentified sugar.

Table IX. The R_f values multiplied by 100 obtained for fructose, glucose, sucrose, and the unidentified sugar using a solvent of butanol-pyridine-water in a v/v ratio of 6:4:3 respectively, and developed at 40°C, for 8 hours

SUGAR	R_f VALUE X 100
Fructose	50.0 - 55.6
Glucose	45.5 - 49.9
Sucrose	30.5 - 33.4
Unidentified Sugar	13.2 - 14.4

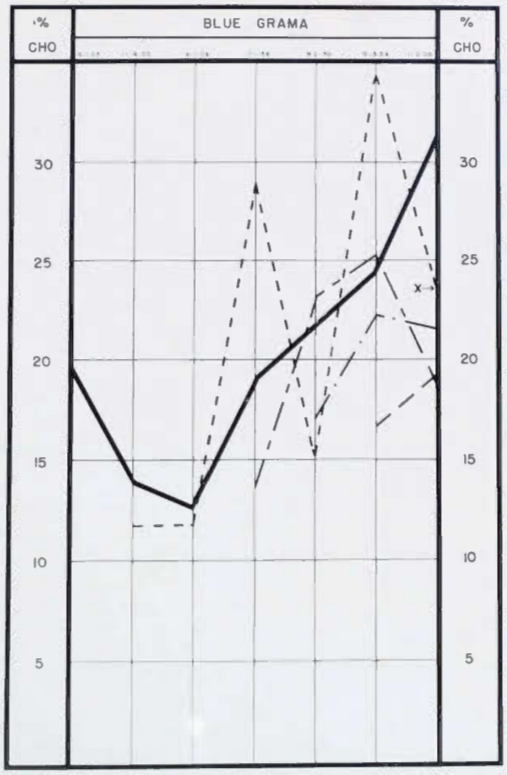

Figure 8. Per cent total carbohydrates for each blue grama series throughout the experiment. Control (solid line), A1 (short dashes), A2 (alternate long and short dashes), A3 (alternate long dashes and dots), A4 (long dashes), and A5 (X).

carbohydrates. This is in accordance with data found by McCarty (1938) working with Bromus carinatus.

This pattern was changed by the stimulus of clipping. There was a consistent decrease in total available carbohydrates during the month following the initial clipping, but a large part of this loss was always gained back the second month after clipping. The fluctuation throughout the growing season was due mainly to changes in sucrose and fructosan content (Table X).

The control (series A6) was not clipped. The carbohydrate content decreased 31 per cent from September 1 to November 4, 1955, when it was 13.7 per cent (Fig. 8). This decrease continued until the early spring growth was completed on about June 1, 1956. Carbohydrates then increased throughout the second season. There was a 53 per cent increase during June when growth was slow. During July, when growth was rapid, the increase in total carbohydrates was only 14 per cent. On September 3 the total carbohydrate content was 24.4 per cent. However, during the period of slow growth and approaching dormancy, there was an increase to 31.4 per cent.

On September 1, 1955, series A1 had a total carbohydrate content in the crowns and roots of 19.8 per cent. It had produced only 190 pounds of foliage, but had stored a fairly large amount of carbohydrates. By November 4 the carbohydrates had decreased to 11.7 per cent. This was undoubtedly due to use of stored reserves for renewing growth after the initial clipping. The drop in carbohydrates was due mainly to a 69 per cent decrease in sucrose.

and fructosans in each blue grama series

Date	Unidenti-fied	Fructose	Glucose	Sucrose	Total sugars	Starch	Fructosans	Total hydrolyzed CHO	Total CHO
				Series A1					
9-1-55	0.2	0.2	0.1	8.1	8.6	4.9	6.3	11.2	19.8
11-4-55	0.1	0.2	0.2	2.5	3.0	4.2	4.5	8.7	11.7
6-1-56	0.1	0.2	0.2	2.0	2.5	4.8	4.5	9.3	11.7
7-1-56	0.3	0.3	0.3	7.0	7.9	7.5	13.5	21.0	28.9
8-2-56	0.3	0.6	0.4	2.9	4.2	5.4	5.4	10.8	15.0
9-3-56	0.3	0.3	0.2	3.8	4.0	10.8	19.1	29.9	34.5
11-2-56	0.5	0.2	0.2	5.2	6.1	8.3	9.5	17.8	23.8
				Series A2					
6-1-56	0.2	0.2	0.2	3.5	4.1	4.8	4.9	9.7	13.8
7-1-56	0.2	0.2	0.2	4.2	4.8	4.2	4.5	8.7	13.5
8-2-56	0.2	0.2	0.2	3.7	4.3	7.2	11.7	18.9	23.2
9-3-56	0.1	0.5	0.4	5.4	6.4	5.4	13.5	18.9	25.3
11-2-56	0.2	0.3	0.2	6.8	7.5	4.9	6.6	11.5	19.0
				Series A3					
7-1-56	0.4	0.2	0.2	4.1	4.9	5.2	9.0	14.2	19.1
8-2-56	0.3	0.2	0.2	4.6	5.3	5.4	6.3	11.7	17.0
9-3-56	0.3	0.4	0.4	5.4	6.5	6.3	9.5	15.8	22.3
11-2-56	0.4	0.5	0.4	7.3	9.7	5.6	6.3	11.9	21.6

(Continued on next page)

Table X. (Continued) The percentage of unidentified sugar, fructose, glucose, sucrose, starch, and fructosans in each blue grama series

Date	Unidentified	Fructose	Glucose	Sucrose	Total sugars	Starch	Fructosans	Total hydrolyzed CHO	Total CHO
					Series A4				
8-2-56	0.3	0.2	0.3	5.4	6.2	6.0	9.6	15.5	21.7
9-3-56	0.4	0.3	0.3	4.0	5.0	5.4	6.3	11.7	16.7
11-2-56	0.3	0.5	0.4	5.8	7.0	6.0	6.3	12.3	19.3
					Series A5				
9-3-56	0.4	0.3	0.2	8.4	9.3	6.3	8.8	15.1	24.4
11-2-56	0.3	0.3	0.2	11.5	12.3	4.9	6.3	11.3	23.6
					Series A6				
9-1-55	0.2	0.2	0.1	8.1	8.6	4.9	6.3	11.2	19.8
11-4-55	0.1	0.2	0.2	3.5	4.0	4.8	4.9	9.7	13.7
6-1-56	0.2	0.2	0.7	1.7	2.8	4.1	5.6	9.7	12.5
7-1-56	0.4	0.2	0.2	4.1	4.9	5.2	9.0	14.2	19.1
8-2-56	0.3	0.2	0.3	5.4	6.2	6.0	9.5	15.5	21.7
9-3-56	0.4	0.3	0.2	8.4	9.3	6.3	8.8	15.1	24.4
11-2-56	0.2	0.2	0.2	15.0	15.6	6.3	9.5	15.8	31.4

Total carbohydrate content on June 1, 1956, was 11.7 per cent, the same as on November 4 of the preceding fall. Growth had begun about April 20 and there was probably some storage occurring; although it would be expected that rapid growth at this time of year would prevent the accumulation of much carbohydrate material. The reducing and non-reducing sugars amounted to only 2.5 per cent, which was their low point for the entire experiment (Table X). There was little additional growth during June. Precipitation was 3.2 inches less than normal while temperature was 3.8° above normal, resulting in poor growing conditions. However, this decrease in growth was accompanied by an increase in total carbohydrates to 28.9 per cent. Sucrose and fructosans increased 250 per cent and 200 per cent, respectively; and were mainly responsible for the increase in carbohydrates (Table X).

During July growing conditions were again favorable and resulted in an increase in yield and a decrease in carbohydrate content to 15 per cent by August 2. This decrease was again due mainly to sucrose and fructosans. The unclipped series contained 21.7 per cent carbohydrates, but series A3, clipped once prior to this, contained only 17.0 per cent.

Series A1 reached a peak in carbohydrate content of 34.5 per cent on September 3. This was more than was present in any other series during the entire experiment. The major part of the increase was due, in this case, to fructosans and starch. This increase was accompanied by a corresponding 41 per cent decrease in foliage yield (Table VI). Series A4, clipped only once prior to this date, contained only 16.7 per cent

carbohydrates. Samples for the final analysis were removed on November 2 after the grass had become dormant. The total carbohydrate content of series A1 had decreased to 23.8 per cent (Fig. 8). This was due primarily to a decrease in fructosans. Such a decrease in total carbohydrates during the fall of the year could result in winter killing and a loss in basal cover (Graber 1927). This series was now 24 per cent lower in carbohydrates than the control series, but contained more than any other series.

Series A2, clipped for the first time on June 1, 1956, had 13.8 per cent carbohydrates as compared to 11.7 per cent for series A1. Starch and fructosans made up 71 per cent of the total. Yield from the quadrats of this series differed little from that of series A1, which had been clipped for the first time on September 1, 1955. Clipping apparently had had little effect on the plants as the total carbohydrate content and yield on July 1 differed but slightly from that of the previous month. The carbohydrate content was 29.0 per cent less than in the control, and 53 per cent less than in series A1. (Fig. 8).

By August 2 Series A2 had accumulated a carbohydrate content of 23.3 per cent, of which starch and fructosans made up 82 per cent. At the same time series A1 had only 15.0 per cent carbohydrates while the control contained 21.7 per cent. Even with this relatively large amount of stored carbohydrates, a yield of 1,093 pounds per acre was produced. This is contrary to the general pattern, since a decrease in carbohydrates was nearly always accompanied by a high yield. However, during July, the total moisture received was 83 per cent above normal while the

temperature was 1.8° below normal. As in all other blue grama series, there was an increase in total carbohydrates the second month following clipping.

On September 2 series A1 and A2 had a foliage height of 3 inches as compared to 6 inches for A4, clipped only once prior to this time. This indicated that continual clipping was lowering the vigor and growth was becoming slower. However, this proved to be the month that series A2 reached a peak in carbohydrates of 25.3 per cent which was more than in any other except A1 (Fig. 8). At this time starch and fructosans made up 75 per cent of the total. During the past month the yield of series A2 decreased 69 per cent while carbohydrates increased 9.5 per cent.

On November 2 carbohydrates for series A2 had decreased by 24 per cent. Starch and fructosans had decreased 9 and 51 per cent, respectively, and sucrose had increased 26 per cent. It may be significant that plants clipped often throughout the growing season suffered a loss in polysaccharides, starch and fructosans, while the non-reducing sugars, and sucrose increased with the approach to dormancy.

Series A3, initially clipped on July 1 produced less foliage during the second season than either A1 or A2 (Table VI). At the time of dormancy carbohydrate content was about the same as in Series A1 and A2 but 31 per cent lower than the control. This indicates that clipping during the middle of the second growing season retarded the storage of carbohydrates. This is reflected again in series A4, clipped for the first time on August (Table X). Although foliage yield was high, being second only to that of series A5

clipped for the first time on September 3, carbohydrate content was low. It was 32 per cent lower on September 3 than the control. However, some of this loss was regained before the plants entered dormancy since there was 19.3 per cent on November 2 (Fig. 8).

Series A5 was not sampled for carbohydrates until November 2 when it had 23.6 per cent carbohydrates. This was almost the same as at the time of clipping. The fact that this loss was so slight may have been due to failure to resume growth after clipping. However, it had 25 per cent less than the control and approximately the same as series A1.

As can be noted in Table X, the percentage of sucrose present in all blue grama series increased with the approach of fall dormancy. The greatest increase was 78 per cent in the control as compared to 37 and 26 per cent, respectively, in A1 and A2. This increase was nearly always accompanied by a decrease in starch and fructosans.

Side-Oats Grama. The carbohydrate content of this grass followed much the same pattern as did that of blue grama; the only exception was that during the month following the initial clipping, it either increased slightly or remained about the same. Fluctuations in carbohydrates of the clipped series, as in blue grama, were due mainly to sucrose and fructosans. The same general pattern of high foliage yield and low carbohydrates was in evidence; although it was not as pronounced as with blue grama (Table XI). The carbohydrate content of the control fluctuated more than in the corresponding blue grama series.

In the control series (B6) the total carbohydrate content increased

from 16.8 to 19.1 per cent from September 1 to November 4, 1955. It then decreased to 14.6 per cent by June 1. At the end of August, after 2 months of rapid growth, it was only 16.7 per cent (Fig. 9). During the next 2 months when growth was slow carbohydrates increased 81 per cent, and by November 2 it contained more than any series. At this time starch and fructosans made up 54 per cent of the total. This is a increase of 46 per cent since September 3 (Table XI). During this same period, sucrose increased 200 per cent.

The grass in series B1, clipped at the close of the first growing season, was 6.0 inches in height and produced 196 pounds of foliage per acre. It had a total carbohydrate content of 16.9 per cent of which 67 per cent was starch and fructosans (Table XI). However, on November 4, 1955, after the grass had entered dormancy, it had a carbohydrate content of 13.0 per cent, which was 32 per cent less than the control (Fig. 9). Sucrose made up 20 per cent of the total in the clipped series and 26 per cent in the control. The loss suffered by series B1 prior to entering dormancy was probably due to additional growth largely from reserves. The grass was then unable to replenish its carbohydrate supply prior to dormancy. The cause for this may have been rapid growth due to precipitation during September.

By June 1, 1956, the total carbohydrate content of series B1 had increased to 21.9 per cent. This is compared to 11.7 per cent in the corresponding blue grama series. The increase in carbohydrates by side-oats grama indicates that they were being produced in excess of those needed for growth and storage was taking place.

Table XI. The percentage of unidentified sugar, fructose, glucose, sucrose, starch, and fructosans in each side-oats grama series

Date	Unidentified	Fructose	Glucose	Sucrose	Total Sugars	Starch	Fructosans	Total hydrolyzed CHO	Total CHO
				Series B1					
9-1-55	0.1	0.2	0.2	5.1	5.6	5.0	6.3	11.3	16.9
11-4-55	0.3	0.3	0.3	2.6	3.5	4.1	5.4	9.5	13.0
6-1-56	0.3	0.3	0.3	3.0	3.9	6.3	11.7	18.0	21.9
7-1-56	0.2	0.2	0.3	2.8	3.5	4.5	4.8	9.3	12.8
8-2-56	0.2	0.2	0.2	5.3	5.9	5.0	9.5	14.5	20.4
9-3-56	0.3	0.3	0.2	5.9	6.7	9.9	15.6	25.5	32.2
11-2-56	0.3	0.2	0.2	4.9	5.0	5.0	7.5	12.5	18.1
				Series B2					
6-1-56	0.1	0.2	0.2	1.9	2.4	5.0	7.2	12.2	14.5
7-1-56	0.3	0.4	0.2	5.4	6.3	6.9	9.6	16.5	22.8
8-2-56	0.2	0.2	0.2	4.5	5.1	5.9	9.5	15.4	22.5
9-3-56	0.3	0.5	0.3	5.3	6.4	6.0	13.5	19.5	25.9
11-2-56	0.3	0.3	0.3	5.3	6.2	5.0	15.8	20.8	27.0
				Series B3					
7-1-56	0.4	0.2	0.3	4.1	5.0	5.0	6.3	11.3	16.3
8-2-56	0.2	0.3	0.3	4.3	5.1	4.3	6.3	10.6	15.7
9-3-56	0.3	0.3	0.3	7.6	8.5	5.5	13.5	19.0	27.5
11-2-56	0.3	0.3	0.2	9.0	9.8	5.0	9.5	14.5	24.3

(Continued on next page)

Table XI. (Continued) The percentage of unidentified sugar, fructose, glucose. sucrose, starch, and fructosans in each side-oats grama series

Date	Unidentified	Fructose	Glucose	Sucrose	Total Sugars	Starch	Fructosans	Total hydrolyzed CHO	Total CHO
				Series B4					
8-2-56	0.3	0.2	0.2	5.0	5.7	6.3	6.3	12.6	18.3
9-3-56	0.2	0.3	0.3	4.2	5.0	5.7	13.5	19.2	24.2
11-2-56	0.3	0.3	0.2	5.2	6.0	5.6	4.5	10.1	16.1
				Series B5					
9-3-56	0.4	0.3	0.2	4.6	5.5	5.0	6.3	11.3	16.8
11-2-56	0.3	1.4	1.4	10.9	14.0	4.8	6.3	11.1	25.1
				Series B6					
9-1-55	0.1	0.2	0.2	5.1	5.6	4.9	6.3	11.2	16.8
11-4-55	0.4	1.0	1.0	5.0	7.4	5.4	6.3	11.7	19.1
6-1-56	0.1	0.2	0.2	1.9	2.4	5.0	7.2	12.2	14.6
7-1-56	0.4	0.2	0.3	4.1	5.0	4.9	6.3	11.2	16.2
8-2-56	0.3	0.2	0.2	4.9	5.6	6.3	6.3	12.6	18.2
9-3-56	0.4	0.3	0.2	4.6	5.5	4.9	6.3	11.2	16.7
11-2-56	0.3	0.3	0.2	13.0	13.8	6.8	9.5	16.3	30.1

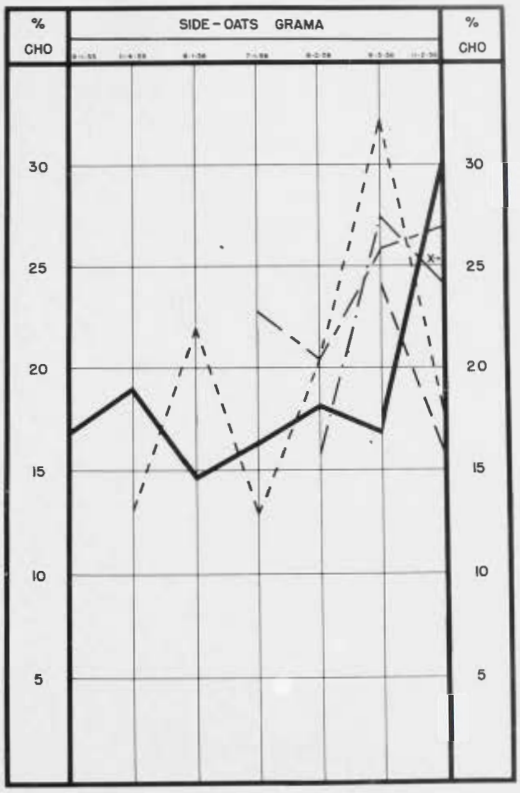

Figure 9. Per cent total carbohydrates for each side-oats grama series throughout the experiment. Control (solid line), B1 (short dashes), B2 (alternate long and short dashes), B3 (alternate long dashes and dots), B4 (long dashes) and B5 (X).

By July 1 total carbohydrate content of series B1 had decreased 42 per cent since June 1. This was 21 per cent less than in the control and 44 per cent less than in B2 (Fig. 9). The foliage yield obtained from series B1 was 26 per cent greater than that from series B2 (Table VIII). This may account for the low carbohydrate content.

During July carbohydrates in series B1 increased 60 per cent while the foliage yield increased 166 per cent. This is the reverse of the usual pattern and was probably due to the excellent growing conditions (Table III).

On September 3, the carbohydrate content of series B1 reached a peak of 32.2 per cent which was the largest amount in any side-oats grama series throughout the experiment. Starch and fructosans made up 80 per cent of the total. Yield had decreased 41 per cent since August 2. The corresponding blue grama series was also at its peak in carbohydrates on this date. From September 3 to November 2 carbohydrates decreased 44 per cent. This decrease was similar to that in the corresponding blue grama series. On November 2 starch and fructosans made up 69 per cent and sucrose 27 per cent of the total carbohydrates. Carbohydrates were 39 per cent lower on November 2 than in the control (Fig. 9).

Series B2, clipped for the first time June 1, 1956, (Table I), contained 14.6 per cent carbohydrates. This was 33 per cent less than that in series B1. The total sugar content was 2.4 per cent, which was the smallest amount in side-oats grama during the experiment. The

corresponding blue grama series was also low in sugars at this time.

By July 1 carbohydrates had increased to 22.8 per cent, while foliage yield had decreased 41 per cent to 430 pounds. The carbohydrate content of series B2 was higher than that of either the control or series B1. The fact that side-oats grama decreased in carbohydrates the second month following the initial clipping may be associated with the fact that, with its rhizomes, it had a larger storage capacity than the slender-rooted blue grama.

During July, series B2 produced 281 per cent more foliage than during the previous month (Table VIII), but carbohydrate content had changed very little. On August 2 sucrose content had decreased to 20 per cent of the total (Table XI). However, total carbohydrates were approximately 19 and 30 per cent greater than in the control and series B3, respectively.

On September 3 series B2 contained 25.9 per cent carbohydrates which was near the peak for the season (Fig. 9). The foliage height attained during August was the least for any month during the second year. During the remainder of the season, carbohydrates continued to increase and reached a maximum of 27.0 per cent at the time of removal of the last sample on November 2 (Table I). Sucrose made up 20 per cent of the total and had fluctuated but little during the season (Table XI).

Series B3 contained 15.7 per cent carbohydrates on August 2 after being initially clipped on July 1. This was less than in any of the other series and was the only treatment in which there was a decrease in carbohydrates in the first month after clipping. One month later, carbohydrate

content had been raised to 27.5 per cent. On November 2, these grasses contained 24.3 per cent carbohydrates. This compares to 18.1 per cent for B1 and 27.0 per cent for B2. Starch and fructosans made up 60 per cent of the total carbohydrates in B3, but sugar content was higher than in the series clipped earlier (Table XI).

Series B4, clipped for the first time on August 2, was second in yield only to B5, thus following the same trend as the corresponding blue grama series. It was 47 per cent lower in carbohydrates at the end of the season than the control and was also lower than any of the other series. Like all other side-oats grama series, B4 increased the second month following clipping. This undoubtedly left the grass in a relatively poor condition for the winter.

Series B5, clipped for the first time on September 3, had a total carbohydrate content of 16.8 per cent (Fig. 9). On November 2 it increased to 25.1 per cent, which was less than that in B2 and B6. Starch and fructosans remained the same while sucrose increased 137 per cent (Table XI). The corresponding series of blue grama did not exhibit this increase in carbohydrates, but remained approximately the same from September to November.

CROWN AND ROOT DEVELOPMENT

Blue Grama. At the close of the first season, the average diameter of the crowns for the control series was only 1.75 inches. The plant examined had 125 roots. Maximum root depth was 26 inches and lateral spread was 14. Few of the main and branch roots extended below 14 inches.

Branching was very extensive in the top 6 inches.

At the close of the second season the roots of the control had penetrated to 62 inches and had a lateral spread of 24. Few of the branch roots penetrated below 51 inches. The plant examined had 736 roots which were of fine texture and extensively branched in the upper 6 inches. The crown from series A1 contained only 519 roots and many of these were young roots around the edge of the crown (Fig. 10). The average diameter of the crowns ranged from 3.5 to 4.5 inches (Fig. 11).

On November 2 the weights of the crowns ranged from 12.7 to 19.8 grams (Table XII). The crowns from the clipped series weighed approximately the same, except for B2 and B5 which weighed almost as much as the control.

Side-Oats Grama. At the close of the first season the side-oats grama crowns averaged 2.0 inches in diameter and had 205 main roots, which had penetrated to a depth of 42 inches and had a lateral spread of 45. As is characteristic of grasses in general, branching was extensive in the upper 6 inches. The crowns from the control had 6 rhizomes, the largest of which was 1 inch long and 1/8 inch in diameter.

By July 1 all plants had young roots. Series B2 and the control had 6 and 12 rhizomes, respectively, but B1 had none. This suggests that clipping had prevented the formation of rhizomes. Roots were also present on the rhizomes from the control plant, but not on those of the clipped plants.

Figure 10. Crowns removed from series B1 (upper left), B6 (upper right), A1 (lower left), and A6 (lower right) on November 2, 1956. The crowns from the unclipped series were larger and better developed than those clipped 5 times. Note the coarseness of the side-oats grama roots

Figure 11. The crowns and top 4 inches of roots from series A1 (left) to series A6 (right) on November 2, 1956. Note the abundance of roots on the crown from series A6

Table XII. Crown weights for each blue grama and side-oats grama series at the close of the 1956 growing season

Series	Weight in grams	
	Blue grama	Side-oats grama
A1 - B1	14.6	21.8
A2 - B2	18.9	21.5
A3 - B3	12.7	27.2
A4 - B4	14.4	20.6
A5 - B5	19.8	31.5
A6 - B6 (Control)	19.5	47.1

On August 2 there were 2 small rhizomes on the plant from series B1, while B2, B3, and the control had 6, 5, and 12, respectively. However, by November 2 a single crown in the control series had 22 rhizomes while the one from series B1, B2, B3, B4, and B5 had 2, 15, 15, 14, and 20 rhizomes, respectively. Roots were present on the large rhizomes only (Fig. 12). The roots of the plant from the control penetrated to a maximum depth of 92 inches with considerable branching in the top 6 inches. The lateral spread was 51 inches as compared to 24 for the corresponding blue grama plant. The control plant had 1,052 roots which was 30 per cent more than the corresponding blue grama. The plant from series B1 had only 514 which was approximately the same as the corresponding blue grama (Fig. 10). This indicates that clipping had reduced root development more in side-oats grama than in the blue grama.

The average diameter of the crowns of the side-oats grama ranged from 4.5 to 6.0 inches. This was slightly more than the diameter of the crowns of blue grama. Crowns from B1, B5, and the control were larger than the others, but B1 was dead or dying in the center. On November 2 the weights ranged from 20.6 to 41.4 grams (Table XII). The clipped series were quite similar and weighed much less than those which had been clipped only once or not at all. In both grasses the crown weights were proportional to the diameter, except for series A1 and B1 where death had occurred in the center.

Figure 12. The crowns and top 4 inches of roots from series B1 (left) to series B6 (right) on November 2, 1956. Note the rhizomes present on the crowns from series B5 and B6

DISCUSSION

Clipping at various times during the growing season had about the same effect on the yields and carbohydrate content of both grasses. Both grasses decreased in total carbohydrates when growing rapidly and increased during periods of slow growth. During periods of rapid growth the plants apparently used carbohydrates in excess of those being produced. In most cases carbohydrate storage in the clipped series reached a peak during August, but the control did not reach a peak until the final sample was taken on November 2. With the approach of dormancy all clipped series showed a decrease in carbohydrates. Blue grama decreased in carbohydrates during the month following the initial clipping and increased the second month. Side-oats grama differed in that carbohydrate content either remained approximately the same or increased the first month following the initial clipping.

High yields were obtained from both grasses when clipping was delayed until September of the second year. This is accounted for by the fact that these plants were allowed to grow unchecked until that time. In the grasses of seriesA3 clipped initially on July 2 production of total foliage at the end of the experiment was less than any of the other blue grama series. However, B3 produced more foliage than did the side-oats grama series clipped earlier. This indicates that clipping retarded growth more in side-oats grama than in blue grama.

The total yield obtained from side-oats grama was consistently higher than from blue grama. For example, side-oats grama clipped only

at the close of the second season produced approximately 50 per cent more foliage than did the corresponding blue grama. This is related to the fact that side-oats grama is a mid grass, growing from 12 to 30 inches in height, while blue grama is a short grass, growing only from 6 to 12 inches. As long as growing conditions are at least fair it is to be expected that side-oats grama will produce more foliage than the shorter blue grama.

Largest partial yields from the series clipped most often throughout the experiment were obtained from both grasses during July. The yield from series A1, A2, B1 and B2 for this month was more than the accumulated yield obtained during May and June. Average production during July and August from series A1, A2, and A3 was approximately 73 per cent of their total yield. Hase (1940) working in this same area obtained yields of 1,584 and 1,415 pounds per acre[3] from blue grama and side-oats grama, respectively. These yields were obtained at the end of a growing season during which the plants were well irrigated and competition from weeds had been at a minimum. This compares to yields of 3,000 and 6,058 pounds for blue grama and side-oats grama, respectively, during the present experiment.

Fluctuations in carbohydrate content were due mainly to fructosans and occasionally to sucrose. Several times fructosan content tripled one month and then decreased approximately the same the following month. For

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[3]Presented in grams in original paper.

example fructosan content in series A1 was 4.5 per cent on June 1 and increased to 13.5 per cent by July 1. Variations in sucrose content were smaller.

From September 3 to November 2 the sucrose content of all grasses either increased or remained approximately the same (Fig. 13). At the same time starch and fructosans usually decreased. Sucrose increased most in the control.

The crowns from series A1, A3, A4, and the corresponding side-oats grama crowns plus B2 were relatively low in weight and carbohydrate content. The diameter of the crowns from series A1 and B1 was large, but their weights were low due to death of older parts in the center. The largest and heaviest were from the control and from the series clipped only once. Also they had more roots, rhizomes, and carbohydrates than the clipped series.

This experiment was conducted only 2 years, but results obtained under these conditions indicate that if it is necessary to utilize a seeded area during the first 2 years it would be best to delay grazing until September of the second growing season. The results show that grass clipped at this time will produce a large yield and still maintain adequate stored carbohydrates. It appears that grazing started during August might result in a high yield, but the storage of carbohydrates would be a a minimum. If the seeded area was grazed throughout the second growing season, low yields, low carbohydrate content, and poorly developed root systems would probably result. This would lead to reduced vigor, fewer seed stalks and viable seeds, and more winter killing.

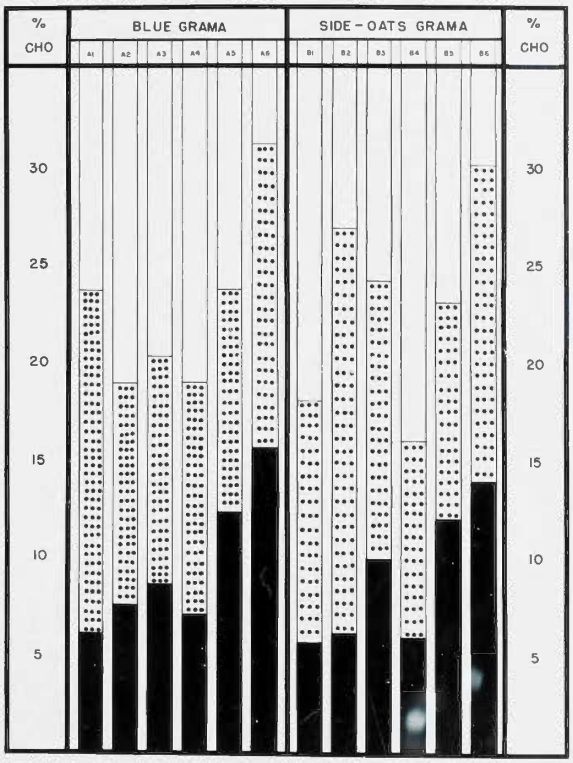

Figure 13. Total sugar (black) and hydrolyzed carbohydrates (dots) for blue grama (right) and side-oats grama (left) on November 2, 1956

SUMMARY

A field and laboratory study was made during 1955 and 1956 to determine the effects of different times of clipping on the yield and carbohydrate content of seeded blue grama (Bouteloua gracilis) and side-oats grama (Bouteloua curtipendula). These grasses were seeded on April 18, 1955. Deficient rainfall was supplemented by irrigation as necessary.

The experimental area was divided into plot A and plot B. Each plot was divided into 6 series and further divided into 6 quadrats. Series A6 and B6 were not clipped during the experiment. Series A1 and B1 were first clipped on September 1, 1955, and on the first of each month throughout the 1956 growing season. Series A2 and B2, A3 and B3, A4 and B4, A5 and B5 were first clipped on June 1, July 1, August 2, and September 3, 1956, respectively, and on the first of each succeeding month thereafter. Blue grama was clipped at a height of 2 inches while side-oats grama was clipped at 3 inches. The herbage removed was air dried, weighed, and converted to pounds per acre.

A sample 6 inches square and 4 inches deep was removed each month of the growing season from September, 1955, to November, 1956, from the unclipped series. A similar sample was removed from each clipped series a month following initial clipping.

Ascending paper chromatography was used for the qualitative and quantitative determinations of reducing sugars, sucrose, starch, and fructosans.

The yield obtained from series A5 and B5 were 3,000 and 6,058 pounds

per acre, respectively. The smallest yield, 2,324 pounds, was produced by series A3. Lowest yield for side-oats grama was the 3,229 pounds produced by B2.

Carbohydrate reserves followed a pattern closely related to the rate of growth. Amount stored decreased when growth was rapid and increased when it was slow.

The carbohydrate content of series A1 was 28.8 per cent on July 1, 1956, after a month of slow growth. However, growth was rapid during July and it decreased to 15.0 per cent. Series A1 reached a peak of 34.8 per cent on September 3 and decreased to 23.8 per cent on November 2. By November 2 series A4 had the least amount of carbohydrates of all series. Series A5, had 24.8 per cent less than the control, which reached a peak of 31.4 per cent.

Sucrose content in blue grama always increased with the approach of dormancy, while starch and fructosans remained approximately the same or decreased. For example, sucrose increased in A5 from 8.4 to 11.5 per cent from September 3 to November 2, while starch decreased from 6.3 to 4.9 per cent and fructosans from 8.8 to 6.3 per cent.

The carbohydrate content in series B1 reached a peak of 32.1 per cent on September 3, 1956, and decreased to 18.1 per cent on November 2. Like blue grama, B4 was the lowest in carbohydrates. B1 had 39.9 per cent less than the control, which had a maximum of 30.1 per cent on November 2. Starch and fructosans were the largest contributors to the reserve foods and in most cases made up at least 70 per cent of the total.

The blue grama crowns removed from the control at the end of the experiment weighed 18.9 grams and had 736 roots; a crown from A1 weighed 14.6 grams and had 519 roots. The crown from B6 weighed 41.4 grams and had 22 rhizomes and 1,052 roots while the one from B1 weighed 21.8 grams and had 2 rhizomes and 514 roots.

The effects of early and continued clipping on these newly seeded grasses were reduced vigor, yield, root reserves, quantity and size of roots, and size of crowns.

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